the rear surface of the other to eliminate quadrature displacement in the tines while maintaining the balance in mass between them.

15. The method of Claim 14 together with the step of removing substantially equal amounts of the balancing masses from same sides of the two tines to adjust the drive mode frequency of the tuning fork.

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16. In a method of manufacturing a tuning fork for use in an inertial rate sensor, the steps of: forming elongated pairs of drive and pickup tines which have front and rear surfaces and extend in opposite directions from a central body, applying balancing masses to the front and rear surfaces of the drive tines, trimming the balancing masses if necessary to provide a balance in mass between the drive tines, and thereafter removing substantially equal amounts of the balancing masses from the front surface of one of the drive tines and from the rear surface of the other to eliminate quadrature displacement in the drive tines while maintaining the balance in mass between them.

17. The method of Claim 16 further including the step of removing substantially equal amounts of the balancing masses from same sides of the drive tines to adjust the drive mode frequency of the tuning fork.

18. The method of Claim 16 further including the steps of applying balancing masses to the pickup tines, and removing substantially equal amounts of the balancing masses from same sides of the pickup tines to adjust the pickup mode frequency of the tuning fork.

Concluded

REMARKS

As requested by the Examiner, the title is being amended and the use of the laser beam is now shown in the drawings, and applicant trusts that the objections to the specification and drawings will be withdrawn.

Claims 7 - 10 and 12 have been rejected under 35 U.S.C. §112 as being indefinite because the Examiner says that they do not particularly point out and distinctly claim the invention. Most of the language to which the Examiner has objected is being eliminated. However, contrary to the Examiner's suggestion, there is no antecedent

problem or uncertainty in with regard to the term "mass" in Claim 7. The balance in mass between the tines is a balancing of the overall masses of the tines, including the tines themselves and the balancing masses, and it is maintained by adjustment of the balancing masses in the manner specified. It would not be correct to say that a balance in the mass of just the enlarged areas is maintained as suggested by the Examiner. With this explanation and the amendments which are being made, applicant trusts that the rejection will be withdrawn.

Claims 4 - 6 have been rejected under 35 U.S.C. §102 as being anticipated by Macy (U.S. 5,522,249). Reconsideration and withdrawal of this rejection is requested.

While applicant's invention and Macy may both be concerned with the elimination of quadrature error, they do so in different ways. In Macy, the pickup electrodes are trimmed to produce an electrical null in the quadrature signal, whereas in applicant's invention balancing masses are utilized to eliminate quadrature vibration and to maintain a balance in mass between the tines. One is an electrical technique; the other is mechanical.

The electrical balancing technique of Macy is quite different than applicant's invention. In the single-ended tuning fork of Macy, piezoelectrically induced drive charge is present on the pickup electrodes. If this charge is not perfectly symmetrical in its distribution on the various pickup electrodes, there will be a net quadrature signal in the output since the drive charge signal is in quadrature phase relation to the rotation-induced Coriolis signal. By trimming away electrode area, an intentional change in the electrode symmetry is created to produce an electrical nulling of the quadrature signal.

Contrary to the Examiner's suggestion, the pickup electrodes in Macy are not balancing masses. Their function is to provide electrically conductive regions for sensing piezoelectrically induced charge, and their mass is insignificant. Such electrodes are typically only 100 - 200 nm thick, whereas balancing masses as

employed in applicant's invention may be as thick as 10,000 nm and a relatively heavy metal such as gold.

The location of the pickup electrodes relatively close to the base of the tines in Macy also makes their mass less significant since they are farther away from the free ends of the tines which move with significantly more velocity than the areas near the base.

In contrast, in applicant's invention, there is a true mechanical balancing in which the mechanical properties of the tines are altered such that the actual quadrature displacement in the pickup mode of vibration is reduced or eliminated.

X Claim 4 is being amended in order to clarify the important difference between applicant's invention and the electrical nulling in Macy. It distinguishes over the prior art in calling for the step of to eliminate quadrature displacement in the tines while maintaining a balance in mass between the tines.

Claim 5 depends from Claim 4 and further distinguishes over Macy in specifying that quadrature displacement is eliminated and mass balance is maintained by applying mass elements to the tines and removing portions of the mass elements from the front surface of one tine and from the rear surface of the other. The fact that the mass is removed from opposite sides of the two tines is important, and it is not even remotely suggested by Macy. Removing mass from only one side of a tine reduces quadrature displacement, and removing it from the opposite side of the other tine increases the reduction. Removing equal amounts from both tines maintains the balance in mass between the tines as the quadrature displacement is eliminated.

Claim 6 also depends from Claim 4 and further distinguishes over Macy in specifying that quadrature displacement is eliminated and mass balance is maintained by adding mass elements to the front surface of one tine and the rear surface of the other tine. As noted above, Macy does not disclose the reduction or elimination of quadrature displacement, and it does not suggest the addition of balancing masses to the tines.

Claims 7, 8 and 10 have been rejected under 35 U.S.C. §103 as being unpatentable over Macy in view of Fujiwara et al. (U.S. 4,468,582). Macy is discussed above, and Fujiwara et al. shows a single piezoelectric plate with electrodes which are trimmed to adjust the frequency of the device. Although the electrodes may be trimmed with a laser, they cannot be trimmed through the plate because they are not offset as in applicant's invention. In that regard, it will be noted that electrode patterns 311, 312 block access to the so-called adjuster electrodes 331, 332 on the opposite sides of the plate.

The Examiner is also mistaken in suggesting that Macy teaches laser trimming of balancing masses affects the pickup and drive mode frequencies of the tuning fork. As discussed in the paragraph bridging Columns 7 and 8 of Macy, the difference in frequency (delta f) between the pickup and drive modes is adjusted by proper dimensioning of the tines and the stem of the fork so that the pickup mode includes torsional rotation of the stem as well as flexing of the tines out of the plane of vibration.

Claim 7 distinguishes over Macy and Fujiwara et al. in calling for the steps of forming a pair of elongated tines having free ends of increased lateral dimension with laterally offset balancing masses on opposite sides of the tines near the free ends, and adjusting the balancing masses on opposite sides of the two tines to eliminate quadrature displacement in the tines while maintaining a balance in mass between the tines. With no teaching of mass balancing or elimination of quadrature displacement in the references, the rejection is clearly improper.

Claim 8 depends from Claim 7 and further distinguishes in specifying that the balancing masses are adjusted by removing substantially equal amounts of them from the opposite sides of the two tines. As discussed above, this technique of removing mass is not even remotely suggested by the references, and it eliminates quadrature displacement without affecting mass balance.

Claim 10 also depends from Claim 7 and further distinguishes over the references in calling for the step of removing substantially equal amounts of the balancing masses

from same sides of the tines to adjust the drive mode frequency of the tuning fork. Neither reference even remotely suggests removing equal amounts of balancing mass from the same sides of the two tines of a tuning fork.

Claim 9 has been rejected under 35 U.S.C. §103 as being unpatentable over Macy in view of Fujiwara et al. and further in view of Praschek et al. (U.S. 5,296,674). Macy and Fujiwara are discussed above, and Praschek et al. is cited as showing the removal of material from one side of a substrate with a laser passing through the substrate. There is no motivation whatsoever for combining the various teachings of these references in the manner proposed by the Examiner, and even if they were combined in that manner, they would not produce the invention.

Claim 9 depends from Claim 7 and distinguishes over the references for the same reasons as its parent claim. In addition, it further distinguishes in specifying that the tines are fabricated of a material which is transparent to a laser beam, and the balancing mass on one side of one of the tines is trimmed by passing the laser beam through the tine to the balancing mass. This is an important improvement in the prior art because it permits the balancing masses on opposite sides of the tines to be trimmed with a laser on one side of the tines. That is not possible in prior art such as Fujiwara et al. where the electrodes are not offset and the electrode on one side would prevent the laser beam from getting to the other.

Claims 11 - 13 have been rejected under 35 U.S.C. §103 as being unpatentable over Macy et al. (U.S. 4,930,351) in view of Macy. Macy is discussed above, and Macy et al. appears to be cited only for its teaching of a double-ended tuning fork. Neither reference even remotely suggests mass balancing and the elimination of quadrature displacement as in applicant's invention.

X

Claim 11 distinguishes over Macy et al. and Macy in calling for the steps of forming an elongated pair of drive tines having front and rear surfaces, forming a pair of pickup tines having front and rear surfaces, applying balancing masses to the front and rear surfaces of the drive tines, and trimming the balancing masses on opposite

sides of the drive tines to eliminate quadrature displacement without affecting mass balance between the drive tines.

Claims 12 and 13 depend from Claim 11 and further distinguish in calling for the steps of trimming the masses on the same sides of the drive and pickup tines to adjust the drive and pickup mode frequencies of the tuning fork. As discussed above, that makes it possible to adjust those frequencies independently of each other and without disturbing either the quadrature displacement or the mass balance.

In order to more fully round out the protection to which applicant is believed to be entitled, new Claims 14 - 18 are being added. Claim 14 distinguishes over the references in calling for the steps of forming a pair of elongated tines which have front and rear surfaces and are disposed symmetrically about an axis, applying balancing masses to the front and rear surfaces of the tines, trimming the balancing masses if necessary to provide a balance in mass between the two tines, and thereafter removing substantially equal amounts of the balancing masses from the front surface of one of the tines and from the rear surface of the other to eliminate quadrature displacement in the tines while maintaining the balance in mass between them.

Claim 15 depends from Claim 14 and further distinguishes in calling for the step of removing substantially equal amounts of the balancing masses from same sides of the two tines to adjust the drive mode frequency of the tuning fork.

Claim 16 distinguishes over the references in calling for the steps of forming elongated pairs of drive and pickup tines which have front and rear surfaces and extend in opposite directions from a central body, applying balancing masses to the front and rear surfaces of the drive tines, trimming the balancing masses if necessary to provide a balance in mass between the drive tines, and thereafter removing substantially equal amounts of the balancing masses from the front surface of one of the drive tines and from the rear surface of the other to eliminate quadrature displacement in the drive tines while maintaining the balance in mass between them.

Claim 17 depends from Claim 16 further distinguishes in calling for the step of removing substantially equal amounts of the balancing masses from same sides of the drive tines to adjust the drive mode frequency of the tuning fork.

Claim 18 also depends from Claim 16 further distinguishes in calling for the steps of applying balancing masses to the pickup tines, and removing substantially equal amounts of the balancing masses from same sides of the pickup tines to adjust the pickup mode frequency of the tuning fork.

With this amendment, it is respectfully submitted that Claims 4 - 18 are all directed to patentable subject matter and that the application is in condition for allowance. Formal drawings will be submitted upon approval of the correction submitted with this amendment.

The Commissioner is authorized to charge any fees required in this matter, including extension fees, to Deposit Account 06-1300, Order No. A-68944/ESW.

Respectfully submitted,

FLEHR HOHBACH TEST
ALBRITTON & HERBERT LLP

By Edward S. Wright

Edward S. Wright
Registration No. 24,903

(650) 494-8700

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Title

[TUNING FORK AND] METHOD OF MANUFACTURING A TUNING FORK WITH REDUCED QUADRATURE ERROR AND SYMMETRICAL MASS BALANCING

Page 4, lines 1 - 2

Figure 3 is a view similar to Figure 2, illustrating the balancing masses [after trimming] being trimmed with a laser to reduce quadrature error.

Page 1, lines 12 - 20

The mass elements can be trimmed by any suitable means such as a laser 30. In one presently preferred embodiment, the tines are fabricated of a material such as crystalline quartz which is transparent to the laser beam, and all of the masses are trimmed from the same side of the fork. Thus, for example, the laser might be positioned on the front side of the fork, with the laser beam 30a passing through the fork to trim elements 28, 29 on the back sides of the tines. Alternatively, if desired, the laser beam can be directed to the back sides of the tines by other means such as mirrors, or by turning the tuning fork over.

Page 6, lines 18 - 24

It is not necessary that the two tines be substantially equal in mass and stiffness prior to adjustment for quadrature offset. If there is an imbalance between the tines, either by design or by errors in fabrication, that imbalance can be corrected by first trimming the mass on one of the tines to eliminate the imbalance, and then trimming equally from both tines for subsequent adjustment. In this way, an inherently asymmetric fork can be corrected as part of the quadrature reduction and frequency adjustment process.

Claims

4. In a method of manufacturing a tuning fork for use in an inertial rate sensor, the steps of: forming a pair of elongated tines which have front and rear surfaces and are disposed symmetrically about an axis, and [providing] using balancing masses on the front surface of one tine and the rear surface of the other tine [which reduce quadrature error signal in the rate sensor output and maintain] to eliminate quadrature displacement in the tines while maintaining a balance in mass between the [two] tines.

5. The method of Claim 4 wherein [the balancing masses are provided] quadrature displacement is eliminated and mass balance is maintained by applying mass elements to the [front surface of one tine and the rear surface of the other] tines, and removing portions of the mass elements from the front surface of one tine and from the rear surface of the other.

6. The method of Claim 4 wherein [the balancing masses are provided by applying] quadrature displacement is eliminated and mass balance is maintained by adding mass elements to the front surface of one tine and the rear surface of the other tine.

7. In a method of manufacturing a tuning fork for use in an inertial rate sensor, the steps of: forming a pair of elongated tines having free ends of [enlarged area] increased lateral dimension with laterally offset balancing masses on opposite sides [of the enlarged area of each] of the tines near the free ends, and adjusting the balancing masses on opposite sides of the two tines to [reduce quadrature error signal in the rate sensor output and to maintain] eliminate quadrature displacement in the tines while maintaining a balance in mass between the [two] tines.

8. The method of Claim 7 wherein the balancing masses are adjusted by removing substantially equal amounts of [mass] them from the opposite sides of the two tines.

9. The method of Claim 7 wherein the tines are fabricated of a material which is transparent to a laser beam, and the balancing mass [is removed from] on one side of one of the tines [with a] is trimmed by passing the laser beam [which is passed] through the tine to the balancing mass.

10. The method of Claim 7 further including the step of removing substantially equal amounts of the balancing masses from [the] same sides of the tines to adjust the drive mode frequency of the tuning fork.

11. In a method of manufacturing a tuning fork for use in an inertial rate sensor, the steps of: forming an elongated pair of drive tines having front and rear surfaces, forming a pair of pickup tines having front and rear surfaces, [providing] applying balancing masses [on] to the front and rear surfaces of the drive tines, and trimming the balancing masses on opposite sides of the drive tines to [reduce quadrature offset error] eliminate quadrature displacement without affecting mass balance between the drive tines.

12. The method of Claim 11 further including the step of trimming the masses on [the] same sides of the drive tines to adjust the drive mode frequency of the tuning fork.

13. The method of Claim 11 further including the steps of providing masses on the pickup tines, and trimming the masses on the pickup tines to adjust the pickup mode frequency of the tuning fork.

14. In a method of manufacturing a tuning fork for use in an inertial rate sensor, the steps of: forming a pair of elongated tines which have front and rear surfaces and are disposed symmetrically about an axis, applying balancing masses to the front and rear surfaces of the tines, trimming the balancing masses if necessary to provide a balance in mass between the two tines, and thereafter removing substantially equal amounts of the balancing masses from the front surface of one of the tines and from the rear surface of the other to eliminate quadrature displacement in the tines while maintaining the balance in mass between them.

15. The method of Claim 14 together with the step of removing substantially equal amounts of the balancing masses from same sides of the two tines to adjust the drive mode frequency of the tuning fork.

16. In a method of manufacturing a tuning fork for use in an inertial rate sensor, the steps of: forming elongated pairs of drive and pickup tines which have front and rear surfaces and extend in opposite directions from a central body, applying balancing masses to the front and rear surfaces of the drive tines, trimming the balancing masses if necessary to provide a balance in mass between the drive tines, and thereafter removing substantially equal amounts of the balancing masses from the front surface of one of the drive tines and from the rear surface of the other to eliminate quadrature displacement in the drive tines while maintaining the balance in mass between them.

17. The method of Claim 16 further including the step of removing substantially equal amounts of the balancing masses from same sides of the drive tines to adjust the drive mode frequency of the tuning fork.

18. The method of Claim 16 further including the steps of applying balancing masses to the pickup tines, and removing substantially equal amounts of the balancing masses from same sides of the pickup tines to adjust the pickup mode frequency of the tuning fork.